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Dielectric and magnetic responses in nanocrystalline $BaTiO_3$

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Barium titanate ($BaTiO_3$) is well known ferroelectrics, which is characterized by diamagnetic properties in the bulk state. However the ultrafine $BaTiO_3$ demonstrates the weak ferromagnetism, as well as a much other ultradispersive oxides. The nature of unusual ferromagnetism in $BaTiO_3$ is not clear up to now. However, it is supposed that ferromagnetism observed in nanostructured materials originated due to point defects, which are predominantly localized on the surface of nanoparticles. Ferroelectric properties of $BaTiO_3$ also depend on lattice defect concentration. Since concentration of lattice defects essentially depends on the thermal annealing regime then the purpose of present work was the study of an influence of sintering temperature and the thermal treatment in H_2 atmosphere on magnetic properties of nanostructured barium titanate.

The ultrafine barium titanate powders produced by Sigma-Aldrich were used for experiments. The initial nanopowders have an average particle size about 100 nm and the cubic perovskite lattice at room temperature. The disc-shaped samples 10 mm in diameter and 1 mm thick were pressed from the powder. These samples were sintered at following regimes. The sample N1 was annealed at 700 °C during 1.0 h; the sample N2 was annealed at 1000 °C for 5.0 h and the sample N3 was firstly annealed at 1000 °C for 5.0 h and then at 1200 °C for 0.5 h.

The temperature dependences of dielectric permittivity (ε) of prepared materials were studied using capacity bridge at a frequency of 10 kHz.

The magnetic measurements were carried out with using a vibrating sample magnetometer at a frequency of measuring magnetic field 10^{-4} Hz and amplitude H_A = 10000 Oe. The error of measured values of magnetization σ does not exceeded of 10%. For magnetic measurements the initial samples and the samples which were sequentially annealed in hydrogen at 250 °C (1.5 h) and 350 °C (1.5 h) were used.

The analysis of our experimental results can be summarized as follows:

1. Different defects in grains surfaces of the nanostructured $BaTiO_3$ are mainly responsible for electron states, which produce ferromagnetic and diamagnetic responses.
2. The annealing of nanostructured $BaTiO_3$ under experimental condition leads to increase in the both ferromagnetic and diamagnetic responses. Observed change of magnetic properties probably due to desorption of absorbed atoms from the surface of nanosizes grains as well as filling of electron states by the electrons that appeared owing to the emptying of the traps when the sample is heated.
3. Increasing the sintered temperature of $BaTiO_3$ nanostructured samples leads to rise of dielectric permittivity and to the decrease of both the ferromagnetic and the diamagnetic responses owing to decrease of lattice defects concentration.
4. Thermal annealing of $BaTiO_3$ nanoparticles with initially cubic perovskite crystalline lattice at temperature ≥ 1000 °C leads to an increase in the dielectric permittivity and to the occurrence of ferroelectric phase transition near $T_C \approx 393$ K.
5. An influence of thermal prehistory on magnetization of nanostructured $BaTiO_3$ should take in account at the analysis of its magnetic properties.

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